

APPENDIX F

Hydrology and Water Quality Data

APPENDIX F

HYDROLOGY AND WATER QUALITY TECHNICAL INFORMATION

This appendix provides further details on the information provided in Section 4.1, “Water Quality and Public Health.” Specifically, this appendix describes 303(d) contaminants of concern, the hydrologic regions in California, and types of disinfection systems.

303(D) CONTAMINANTS OF CONCERN

Table 4.1-1 in Section 4.1, “Water Quality and Public Health,” identifies typical pollutants on the Section 303(d) list that are likely to be present in onsite wastewater treatment system (OWTS) effluent. Table F-1 provides a complete listing of pollutants of concern as identified by the Regional Water Quality Control Boards (Regional Water Boards).

Table F-1 Typical Pollutants of Concern in 303(d) Contaminant List by Regional Water Board									
Pollutant	Central Coast	Central Valley	Colorado River Basin	Lahontan	Los Angeles	North Coast	San Diego	San Francisco Bay	Santa Ana
General									
Biological oxygen demand		X							
Low dissolved oxygen (DO)	X	X			X	X	X	X	
Organic enrichment/low DO	X	X	X	X	X	X		X	X
Sedimentation/siltation	X	X	X	X	X	X	X	X	X
Suspended solids									X
Turbidity						X	X		
Bacteriologic									
Bacteria		X							
Bacteria indicators					X		X		
Beach closures (coliform)					X				
Enteric viruses					X				
Enterococci							X		X
Fecal coliform	X	X			X		X		X
High coliform count		X		X	X			X	X
Pathogens	X	X	X	X	X	X		X	X
Total coliform	X				X				X
Nutrient									
Nitrate	X				X				

Table F-1
Typical Pollutants of Concern in 303(d) Contaminant List by Regional Water Board

Nitrate and nitrite					X				
Nitrate as nitrate (NO ₃)					X				
Nitrate as nitrogen					X				
Nitrite as nitrogen					X				
Nitrogen				X	X	X	X		
Nutrients	X	X	X	X		X	X	X	X
Nutrients (algae)					X				
Phosphorus				X		X	X		
Dissolved Inorganic Compounds									
Boron	X	X			X				
Chloride	X			X	X		X		
Hydrogen sulfide								X	
Salinity			X						
Salinity/TDS/chlorides	X			X				X	X
Sodium	X			X					
Specific conductivity					X				
Sulfates				X	X		X		
Metals									
Arsenic ¹		X		X					
Cadmium ¹		X			X		X		
Cadmium, dissolved					X				
Copper		X		X	X		X		X
Copper, dissolved					X		X		
Iron				X					
Lead ¹		X			X		X		
Lead, dissolved					X				
Manganese				X					
Mercury ¹	X	X			X	X	X	X	X
Metals	X	X		X				X	X
Nickel		X			X		X	X	X
Selenium		X	X		X			X	
Selenium, total					X				
Silver				X					
Zinc		X			X		X		
Zinc, dissolved					X				

Table F-1
Typical Pollutants of Concern in 303(d) Contaminant List by Regional Water Board

Selected Organic Compounds									
Chlordane ²							X	X	
Dioxin ^{1,2}		X							
Dioxin compounds ^{1,2}								X	
HCH (tissue) ¹					X				
Lindane ²							X		
M,p,-Xylenes ²			X						
O-Xylenes ²			X						
Toluene ²			X						
Trichloroethylene/TCE ²					X				
Pesticides	X	X	X		X		X		X
Priority organics	X			X					X
¹ Endocrine-disrupting compounds (Source: Colborn, Dumanoski, and Peterson Myers 2005)									
² Source: EPA 2002									

The following text details how metals listed as 303(d) contaminants of concern affect public health. This information serves as background information to the setting discussion and impact analysis provided in Section 4.1, “Water Quality and Public Health.”

METALS

Metals in drinking water cause human health problems. Metals including lead, mercury, cadmium, copper, and chromium can cause physical and mental developmental delays, kidney disease, gastrointestinal illnesses, and neurological problems (DeWalle et al. 1985). In the aquatic ecosystem, metals are also toxic to aquatic life and accumulate in fish and shellfish that might be consumed by humans. Metals can exist in raw household wastewater from commonly used household products; aging interior plumbing systems that can contribute lead, cadmium, and copper; foodstuffs; and human waste (EPA 2002).

Several U.S. Environmental Protection Agency (EPA) priority pollutant metals have been found in domestic septic tank effluent (including nickel, lead, copper, zinc, barium, and chromium), although at low concentrations. Copper and zinc were the only trace metals found in any significant amounts, and those concentrations were less than in tap water (Whelan and Titmanis 1982). Reviews and studies to date, although not extensive, suggest there is very little concern over heavy metals in domestic septic tank effluent (Siegrist, Tyler, and Jenssen 2000). The fate of metals in soil is varied and depends on complex physical, chemical, and biochemical interactions. Although studies appear to indicate possible removal of metals in both septic tanks and soils, some risk remains and groundwater contamination in specific cases is possible (EPA 2002).

Dissolved metals typically form cations, positively charged ions (e.g., Fe_2^+ , Zn^{+2}). Negatively charged ions such as NO_3^- are anions. The primary processes controlling the fixation or mobility potential of metals in subsurface infiltration systems are adsorption onto negatively charged soil particles and interaction with organic molecules. The solubility of metals is pH dependent, and tends to be lowest between pH 6 and 8. Acidic conditions can reduce the sorption of metals in soils, leading to increased solubility and therefore increased risk of groundwater

contamination (Evanko and Dzombak 1997, EPA 2002). A ligand is an atom, ion, or molecule that binds to the metal ion. Low solubility metal compounds are formed by complexation with inorganic (e.g., Cl^- , CO_3^{2-} , SO_4^{2-} , PO_4^{3-}) and organic ligands (e.g., humic and fulvic acids, amino acids) (Evanko and Dzombak 1997). All metal ions in water are hydrated, i.e., they form complexes with hydrogen oxide (H_2O). Increasing the pH (i.e. adding hydroxyl $[\text{OH}^-]$ ions) can precipitate insoluble metal complexes out of solution (Schnoor 1996).

ARSENIC

Arsenic occurs naturally in the environment and is generally combined with oxygen, chlorine, and sulphur to form inorganic arsenic compounds. It is also present in ashes from coal combustion. Arsenic exhibits fairly complex chemistry and can be present in several oxidation states. Many arsenic compounds sorb strongly to soils and are therefore fairly immobile in groundwater and surface water (NPI 2007a, Evanko and Dzombak 1997).

The sources of arsenic listed as contaminating impaired waters in California under Section 303(d) are resource extraction, geothermal development, flow regulation/modification, natural sources, and nonpoint sources.

CADMIUM

The sources of cadmium (Cd) listed as contaminating impaired waters in California under Section 303(d) are nonpoint and point sources and resource extraction. Cadmium is relatively mobile in surface water and groundwater systems and exists primarily as the Cd^{2+} ion or as complexes with humic acids and other organic ligands (Evanko and Dzombak 1997). Under acidic conditions, cadmium may also form complexes with chloride and sulfate. Cadmium is removed from natural waters by precipitation and sorption to mineral surfaces, especially oxide minerals, at higher pH values ($>\text{pH } 6$). Removal by these mechanisms increases as pH increases. Sorption is also influenced by the cation exchange capacity of clays, carbonate minerals, and organic matter present in soils and sediments (Evanko and Dzombak 1997).

COPPER

Copper (Cu) is an essential micronutrient for plants and animals, but is toxic at higher levels. Alkalinity and pH are other factors that influence copper toxicity. Mining activities are the major source of copper contamination in groundwater and surface waters (Evanko and Dzombak 1997). Aging interior plumbing systems can contribute copper, as well as lead and cadmium (EPA 2002). The sources of copper listed as contaminating impaired waters in California under Section 303(d) are nonpoint and point sources, resource extraction, urban runoff and storm sewers, mine tailings, and unknown sources.

Copper forms strong solution complexes with humic acids and is normally bound in soil. The affinity of Cu for organic ligands increases as pH increases. Copper mobility is decreased by sorption to mineral surfaces. Cu^{2+} sorbs strongly to mineral surfaces over a wide range of pH values (Evanko and Dzombak 1997). The cupric ion (Cu^{2+}) is the most toxic species of copper. Its toxicity increases with decreasing water hardness and dissolved oxygen concentration, and decreases with high concentrations of dissolved organic compounds and suspended solids (NPI 2007b).

CHROMIUM

Chromium (Cr) does not occur naturally in elemental form, only in compounds. Chromium is usually found as the Cr (III) form, as the mineral Chromite, and in many soils. Cr (VI), known as hexavalent chromium, is the more toxic form and is also more mobile. Chromium (VI) compounds are formed by industrial processes and do not occur naturally. Cr (III) mobility is decreased by adsorption to clays and oxide minerals at lower pH values (<5) and low solubility above pH 5. Soluble and unadsorbed chromium complexes can leach from soil into groundwater. The leachability of Cr (VI) increases as soil pH increases. Most of chromium released into natural waters is particle associated, however, and is ultimately deposited into the sediment (Evanko and Dzombak 1997).

The sources of chromium listed as contaminating impaired waters in California under Section 303(d) are industrial point sources, nonpoint and point sources, and combined sewer overflow.

LEAD

Lead is a metal identified as a pollutant on EPA's Section 303(d) list, with resource extraction (i.e., mining activities), nonpoint, and point sources being the main contributors. Most lead that is released to the environment is retained in the soil. The amount of dissolved lead in surface water and groundwater depends on pH and the concentration of dissolved salts and the types of mineral surfaces present. In surface water and groundwater systems, a significant fraction of lead is undissolved and occurs as precipitated complexes, sorbed ions, or as suspended organic matter (Evanko and Dzombak 1997).

MERCURY

Mercury is found in natural deposits or as cinnabar ore, the common ore of mercury in the form of mercury sulfide. Substantial contamination occurred in many areas of California in association with the historical use of mercury in gold mining and refining operations. Other mercury sources may include manufactured products (e.g., batteries, fluorescent light bulbs, electrical switches, thermometers), and a variety of processes (e.g., combustion of fossil fuels, incineration of wastes, cement production, metal refining) (EPA 2002). The sources of mercury listed as contaminating impaired waters in California under Section 303(d) are as follows:

- ▶ source unknown,
- ▶ natural sources,
- ▶ resource extraction,
- ▶ nonpoint source,
- ▶ industrial point sources,
- ▶ minor industrial point source,
- ▶ municipal point sources,
- ▶ atmospheric deposition,
- ▶ mine tailings,
- ▶ surface mining,
- ▶ nonpoint/point source, and
- ▶ acid mine drainage.

After release to the environment, mercury usually exists in mercuric (Hg^{2+}), mercurous (Hg_2^{2+}), elemental (Hg), or alkylated form (methyl/ethyl mercury). In the aquatic environment, mercury is a toxic and bioaccumulative substance in both inorganic and methylated organic forms. Methyl mercury is the most hazardous form of mercury because of its chemical stability and ionic properties that allow it to penetrate cell membranes and accumulate in tissues of aquatic organisms (Eisler 1987).

The redox potential and pH of the substrate determine the stable forms of mercury that will be present. Mercurous and mercuric mercury are more stable under oxidizing conditions. When mildly reducing conditions exist (e.g., lower redox potential) organic or inorganic mercury may be reduced to elemental mercury, which may then be converted to alkylated forms by biotic or abiotic processes. Hg (II) forms strong complexes with many types of inorganic and organic ligands, making it very soluble in oxidized aquatic systems. Sorption to soils, sediments, and humic materials is an important mechanism for removal of mercury from solution. Sorption is pH-dependent and increases as pH increases (Evanko and Dzombak 1997).

ZINC

Zinc is an essential micronutrient for plants and animals, but is toxic at higher levels. Zinc is one of the most mobile heavy metals in surface waters and groundwater because it is present as soluble compounds at neutral and

acidic pH values. Zinc usually occurs in the +II oxidation state and forms complexes with a number of anions, amino acids, and organic acids. In aquatic environments zinc is usually sorbed to sediments or suspended solids including hydrous iron and manganese oxides, clay minerals, and organic matter. Sorption of zinc increases as pH increases and salinity decreases (Evanko and Dzombak 1997). The sources of zinc listed as contaminating impaired waters in California under Section 303(d) are nonpoint and point sources and resource extraction.

HYDROLOGIC REGIONS OF CALIFORNIA

The hydrologic regions of California are summarized below, including dominant hydrogeological features, water quality issues of concern, and septic tank discharge prohibition areas. The information was obtained from the Regional Water Board water quality control plans (basin plans), the California Department of Water Resources (DWR) *Bulletin 118, California Water Plan Update 2005* (DWR 2005), and other sources where noted.

NORTH COAST HYDROLOGIC REGION

The North Coast hydrologic region covers approximately 12.46 million acres (19,470 square miles) and encompasses the counties of Siskiyou, Del Norte, Trinity, Humboldt, Mendocino, Sonoma, and small areas of Marin. The region, extending from the Oregon border south to Tomales Bay, includes portions of four geomorphic provinces—the northern Coast Range, the Mad River drainage, the Klamath Mountains, and the coastal mountains. The majority of the population is located along the Pacific Coast and in the inland valleys north of the San Francisco Bay Area. The northern mountainous portion of the region is rural and sparsely populated, and most of the area is heavily forested. A majority of the surface water in the North Coast hydrologic region is committed to environmental uses because of the “wild and scenic” designation of most of the region’s rivers. Average annual precipitation in this hydrologic region ranges from 100 inches in the Smith River drainage to 29 inches in the Santa Rosa area.

Water bodies that provide municipal water include the Smith, Mad, and Russian Rivers. Areas providing agricultural water are more widespread than those for domestic, municipal and industrial use, as they occur in all of the hydrologic units within the region. Many of the smaller communities and rural areas are generally supplied by small local surface water and groundwater systems. Water recreation occurs in all hydrologic units on both fresh and salt water, attracting over 10 million people annually. Coastal areas receiving the greatest recreational use are the ocean beaches, the lower reaches of rivers draining to the ocean, and Humboldt and Bodega Bays. The Russian, Eel, Mad, Smith, Trinity, and Navarro Rivers and Redwood Creek provide the most freshwater recreational use.

The water quality priorities in this region are focused on nonpoint source runoff from logging, rural roads, agriculture, and urban areas, with nutrients, low dissolved oxygen (DO), sediments, siltation, and temperature the primary contaminants in the Regional Water Quality Control Board’s (Regional Water Board’s) 303(d) list of impaired water bodies. Along the coast, in addition to the eutrophication problems discussed in Section 4.1 under “Nitrogen” and “Phosphorus,” nonpoint-source pollution can cause microbial contamination of shellfish growing areas, especially oysters. In the southern portion of the region, the development of new hillside vineyards is an increasing source of erosion and pesticides that potentially make their way to water bodies. There are two Septic Tank Discharge Prohibition Areas (established by the North Coast Regional Water Board in 1988) for the North Coast region, both in the southern portion of the region in Sonoma County. These are the Larkfield Area and the Willside Estates Area.

Groundwater quality characteristics and specific local impairments vary with regional setting within the region. In general, seawater intrusion and nitrates in shallow aquifers are problems in the coastal groundwater basins; high total dissolved solids (TDS) content and general alkalinity are problems in the lake sediments of the Modoc Plateau basins; and iron, boron, and manganese can be problems in the inland basins of Mendocino and Sonoma counties. Of the 584 public supply water wells sampled in 32 of the 63 basins and subbasins in the North Coast hydrologic region from 1994 through 2000, analyzed samples indicate that 553 wells, or 95%, met the state

primary maximum contaminant levels (MCL) for drinking water. Thirty-one wells, or 5%, sampled had constituents that exceed one or more MCL.

SAN FRANCISCO BAY HYDROLOGIC REGION

The San Francisco Bay hydrologic region covers approximately 2.88 million acres (4,500 square miles) and encompasses the project counties of San Francisco and portions of Marin, Sonoma, Napa, Solano, San Mateo, Santa Clara, Contra Costa, and Alameda. Significant geographic features include the Santa Clara, Napa, Sonoma, Petaluma, Suisun-Fairfield, and Livermore valleys; the Marin and San Francisco peninsulas; San Francisco, Suisun, and San Pablo bays; and the Santa Cruz Mountains, Diablo Range, Bolinas Ridge, and Vaca Mountains of the Coast Range. Major rivers in this hydrologic region include the Napa and Petaluma, which drain to San Francisco Bay. Although this is the smallest hydrologic region in the state, it contains the second largest human population. In the San Francisco Bay hydrographic region, the 303(d) listed contaminants are primarily metals and organics. Total maximum daily loads (TMDLs) are proposed or completed for these contaminants in nine high-priority project watersheds.

The region generally has only local groundwater quality impairments. The primary constituents of concern for groundwater in this region are high TDS, nitrate, boron, and organic compounds. Elevated levels of nitrate have been detected in a large percentage of private wells tested within subbasins located south of the Santa Clara Valley. Persistent nitrate contamination has also been shown in the shallow aquifer zone within the Petaluma Valley. Sampling of 485 public supply water wells from 1994 through 2000 in 18 of the regions 33 basins and subbasins indicate that 410 wells, or 85%, met the state primary MCLs for drinking water standards. Seventy-five wells, or 15%, have constituents that exceed one or more MCL. There are four Discharge Prohibition Areas in the San Francisco Bay Region—the Stinson Beach Area in Marin County; the Glen Ellen Area in Sonoma County; and Emerald Lake Hills and Oak Knoll Manor, both in San Mateo County.

CENTRAL COAST HYDROLOGIC REGION

The Central Coast hydrologic region covers approximately 7.22 million acres (11,300 square miles) in central California, and includes all of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara Counties, most of San Benito County, and parts of San Mateo, Santa Clara, and Ventura Counties.

Regional surface water quality concerns in this region include elevated concentrations of nitrate and perchlorate found in the southern portion of Santa Clara County. The Salinas River watershed has significant nitrate contamination related to agriculture, the valley's main land use. Nutrients and pathogens from septic systems affect the San Lorenzo River Basin, horse corrals, and urban runoff, as well as erosion from logging, urban development, and road maintenance. Elevated bacterial levels in Elkhorn slough, a tributary to Monterey Bay, may be associated with a large dairy and waste operation in the watershed as well as septic tanks.

Groundwater is the primary source of water in the region, accounting for approximately 75% of the annual supply. Much of the groundwater in the region is characterized by mineral types such as calcium sulfate and calcium sodium bicarbonate sulfate, which are caused by marine sedimentary rock in the watersheds. Aquifers intruded by seawater are typically characterized by sodium chloride and calcium chloride, and have chloride concentrations greater than 500 milligrams per liter. A number of groundwater basins are affected by salinity, and seawater intrusion is a problem in the shallow groundwater aquifer around Castroville because of overdrafting of water. In several areas, groundwater exceeds the MCL for nitrate. Sampling of 711 public supply water wells from 1994 through 2000 in 38 of the regions' 60 basins and subbasins indicates that 587 wells, or 83%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 17%, or 124 wells. There are two Discharge Prohibition Areas in the Central Coast Region, both in San Luis Obispo County: the Los Osos/Baywood Park Area and Portions of the City of Nipomo.

SOUTH COAST HYDROLOGIC REGION

The South Coast hydrologic region includes all of Orange County; most of San Diego and Los Angeles Counties; parts of Riverside, San Bernardino, and Ventura Counties; and a small portion of Kern and Santa Barbara Counties. Because it is the most populous area of the state, it is divided into 3 Regional Board regions. Region 4, Los Angeles, encompasses portions of Ventura and Los Angeles counties. Region 8, Riverside, encompasses portions of San Bernardino, Riverside, and Orange Counties. Region 9, San Diego, encompasses portions of Orange, Riverside, and San Bernardino Counties. Approximately half of California's population, or about 17 million people, live within the boundaries of the South Coast hydrologic region. This, combined with its comparatively small surface area of approximately 6.78 million acres (10,600 square miles) gives it the highest population density of any hydrologic region in California. Major population centers include the metropolitan areas surrounding Ventura, Los Angeles, San Diego, San Bernardino, Orange County, and Riverside.

Water use efficiency measures and water recycling efforts play a significant role in addressing increasing water use caused by population growth. The major surface water quality issues in the South Coast hydrologic region include storm water and urban runoff, sanitary sewer overflows, ocean outfalls, and resulting tidal input that can degrade coastal water quality and cause beach closures. TDS and emergent contaminants such as pharmaceutical and personal care products, disinfection byproducts, perchlorate, arsenic, nitrosodimethylamine, hexavalent chromium, and methyl tertiary butyl ether are also contaminants of concern.

Groundwater is what supplies approximately 23% of the region's water in normal years and about 29% in drought years. There are 56 groundwater basins in the region. The high salinity of imported Colorado River water is also a concern, limiting reuse and groundwater recharge potential. Perchlorate is an emergent contaminant of concern in several areas in the South Coast hydrologic region. The Los Angeles subregion contains areas with contamination plumes consisting mainly of trichloroethylene and tetrachloroethylene. Groundwater in basins of the Santa Ana subregion has local impairments from nitrates and volatile organic compounds. Local impairments by nitrate, sulfate, and TDS are found in the San Diego subregion. Sampling of 2,342 public supply water wells from 1994 through 2000 in 47 of the region's 73 basins and subbasins indicate that 1,360 wells, or 58%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 42%, or 982 wells. Discharge Prohibition Areas are located in Oxnard Forebay in Ventura County. Region 8 contains the following Discharge Prohibition Areas:

- ▶ Grand Terrace (CSD 70, Improvement Zone H),
- ▶ Yucaipa and Calimesa (Yucaipa Valley County Water District),
- ▶ Lytle Creek (above 2,000 foot elevation),
- ▶ Mill Creek (above the 2,600 foot elevation),
- ▶ Bear Valley (includes the Baldwin Lake drainage area),
- ▶ Homeland-Green Acres, and
- ▶ Romoland.

No Discharge Prohibition Areas are located in Region 9.

CENTRAL VALLEY HYDROLOGIC REGION

The Central Valley hydrologic region is the largest in California, and encompasses the three subregions described below. This region contains the largest number of Discharge Prohibition Areas, as follows:

- ▶ Amador County—Amador City; Martell Area
- ▶ Shasta County—Shasta Dam Area Public Utilities District; Fall River Mills, Community Services District; Anderson-Cottonwood Irrigation District, Community of Cottonwood

- ▶ Calaveras County—Vallecito Area; West Point Area; Arnold Area; Six-Mile Village
- ▶ Merced County—Celeste Subdivision Area; Snelling Area; Midway Community Services District
- ▶ Nevada County—North San Juan
- ▶ Contra Costa County—Contra Costa County Sanitation District No. 15
- ▶ Madera County—Madera County Service Area No. 3, Bass Lake; Madera County Service Area No. 1, Parksdale
- ▶ Mariposa County—Coulterville County Service Area No. 1
- ▶ Modoc County—Adin Community Services District; Daphnedale Area
- ▶ Placer County—Bell Road Community, including Panorama and Pearl
- ▶ Lake County—Nice and Lucerne; Communities of Clearlake Highlands and Clearlake Park; Community of South Lakeshore Assessment District
- ▶ Sacramento County—Courtland Sanitation District
- ▶ Plumas County—Taylorsville County Service Area
- ▶ Butte County—Chico Urban Area
- ▶ Tulare County—East Porterville Area
- ▶ Kings County—Home Garden Community Services District; Kettleman City County Service Area No. 1; Corcoran Fringe Area

SACRAMENTO RIVER HYDROLOGIC SUBREGION

The Sacramento River hydrologic subregion, which corresponds to roughly the northern third of the Central Valley Regional Board, covers 27,246 square miles and includes all or a portion of 20 predominately rural northern California counties. The subregion extends from the crest of the Sierra Nevada in the east to the summit of the Coast Range in the west, and from the Oregon border north downstream to the Sacramento–San Joaquin River Delta (Delta). It includes the entire drainage area of the Sacramento River, the largest river in California, and its tributaries.

Surface water quality in the hydrologic subregion is generally good, although possible sources of contamination that can affect water quality include turbidity, pesticides and fertilizer from agricultural runoff, high water temperatures, and toxic heavy metals, such as mercury, copper, zinc, and cadmium from acid mine drainage.

Groundwater quality in the Sacramento River subregion is generally good, although there are localized problems. Naturally occurring salinity impairs wells at the north end of the Sacramento Valley. Hydrogen sulfide is a problem in wells in the geothermal areas in the western part of the region. Localized nitrate pollution associated with agriculture and OWTS occurs throughout the hydrologic region. Contamination from OWTS is an issue of particular concern in Butte County, where 150,000 of its 200,000 residents rely upon individual septic systems. These systems are often inappropriately sited in shallow, unconfined or fractured hard rock aquifers, where insufficient soil depth is available for necessary unsaturated flow. Sampling of 1356 public supply water wells from 1994 through 2000 in 51 of the 88 basins and subbasins in the region indicate that 1,282 wells, or 95%, met

the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 5%, or 74 wells.

SAN JOAQUIN RIVER HYDROLOGIC SUBREGION

The San Joaquin River hydrologic subregion is bordered on the east by the Sierra Nevada and on the west by the coastal mountains of the Diablo Range, and extends from the southern boundaries of the Delta to the northern edge of the San Joaquin River in Madera. It consists of the drainage area of the San Joaquin River, which at approximately 300 miles long is one of California's longest rivers. The San Joaquin River hydrologic subregion, which corresponds to roughly the middle third of the Central Valley Regional Water Board, covers approximately 9.7 million acres (15,200 square miles). Roughly half of the Delta is within this hydrologic region, which extends south from just below the northeastern corner of Sacramento County and east to include the southern third of El Dorado County, almost all of Amador County, all of Calaveras, Mariposa, Madera, Merced, Stanislaus, and Tuolumne counties, the western slope of Alpine County, and the portions of the Delta in Contra Costa, Alameda, and San Joaquin Counties.

Some of the major causes of water quality impairments in the subregion include depleted freshwater flows, municipal and industrial wastewater discharges, salt loads from agricultural drainage and runoff, and other pollutants associated with long-term agricultural irrigation and production, including nutrients, selenium, boron, and organophosphate pesticides. The Central Valley Regional Water Board identified high-priority water quality problems in their latest basin plan review as salinity and boron discharges to the San Joaquin River, low DO problems in the lower San Joaquin River, control of organophosphorous pesticides, and the need for more stringent protections for Delta drinking water quality.

The groundwater quality throughout the hydrologic subregion is generally good and useable for most urban and agricultural uses with only local impairments. The water quality of the Yosemite Valley groundwater basin is exceptionally high. The primary constituents of concern in the San Joaquin hydrologic region are TDS, nitrate, boron, chloride, and organic compounds. Areas of high TDS content are primarily along the west side of the San Joaquin Valley and in the San Joaquin valley trough. The high TDS content of the westside groundwater is caused by streamflow recharge originating from marine sediments in the Coast Range. High TDS, boron, and chloride content in the trough of the valley are the result of concentration of salts due to evaporation and poor drainage. Major anthropogenic sources of nitrates in the region include human and animal waste products and agricultural runoff. Sampling of 689 public supply water wells from 1994 through 2000 in 10 of the region's 11 basins and subbasins indicate that 523 wells, or 76%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 24%, or 166 wells.

TULARE LAKE HYDROLOGIC SUBREGION

The Tulare Lake hydrologic subregion is located in the southern end of the San Joaquin Valley, and includes all of Tulare and Kings Counties and most of Fresno and Kern Counties. Major cities include Fresno, Bakersfield, and Visalia. The region, which corresponds to approximately the southern third of the Central Valley Regional Water Board, covers approximately 10.9 million acres (17,000 square miles).

Contaminants of concern in the Tulare Lake hydrologic subregion that affect both groundwater and surface water beneficial uses include salinity, nitrate, pesticides, and selenium. Agricultural runoff and drainage are the main sources of these. The subregion also has a relatively large concentration of dairies that contribute pathogens, salinity, and nutrients to both surface water and groundwater. Nitrate has contaminated more than 400 square miles of groundwater in the region (DWR 2005). In addition, oilfield waste has degraded water quality. According to the Central Valley Regional Water Board's basin plan, there are more than 800 oilfield waste dischargers, of which 250 are regulated under waste discharge requirements. Sampling of 1,476 public supply water wells from 1994 through 2000 in 14 of the 19 basins and subbasins in the region indicate that 1,041 wells,

or 71%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 29%, or 427 wells.

LAHONTAN HYDROLOGIC REGION

The Lahontan hydrologic region encompasses two subregions: the North Lahontan, extending north from the Oregon border near Mono Lake on the east side of the Sierra, and the South Lahontan, extending south to the crest of the San Gabriel and San Bernardino mountains and the divide between watersheds draining south toward the Colorado River and those draining northward. This region contains the following Discharge Prohibition Areas:

- ▶ Lassen County—Cady Springs Area; Spaulding Tract and Stone-Bengard Subdivisions
- ▶ Placer County—Truckee River Hydrologic Unit above Boca River confluence; Glenshire and Devonshire Subdivisions
- ▶ Mono County—Rush Creek above Grant Lake; Mammoth Creek watershed; Hilton Creek/Crowley Lake Communities
- ▶ Inyo County—Assessment Districts No. 1 and No. 2; Rocking K Subdivision; City of Bishop
- ▶ San Bernardino County—Silverwood Lake; Deep Creek and Grass Valley Creek Watersheds above 3200 feet; Desert Knolls Community

NORTH LAHONTAN HYDROLOGIC SUBREGION

The North Lahontan hydrologic subregion extends south from the Oregon border approximately 270 miles to the South Lahontan subregion. Extending east to the Nevada border, it consists of the western edge of the Great Basin, and water in the region drains eastward toward Nevada. The subregion, corresponding to approximately the northern half of the Lahontan Regional Water Board, covers approximately 3.91 million acres (6,110 square miles) and includes portions of Modoc, Lassen, Sierra, Nevada, Placer, El Dorado, Alpine, Mono, and Tuolumne Counties.

In general, the water quality in the North Lahontan hydrologic subregion is good, with contaminants of concern occurring locally. Water quality is an issue of concern for many surface water systems around Lake Tahoe. The abandoned Leviathan Mine, a Superfund site in the upper reaches of the Carson River watershed, affects local creeks with acid mine drainage water. High-priority water quality issues arising from the Lahontan Regional Water Quality Board 2003 Triennial Review included proposals to revise the waste discharge prohibition for piers in Lake Tahoe and sodium standards for the Carson and Walker Rivers and their tributaries.

In basins in the northern portion of the subregion, groundwater quality is widely variable. Wells that obtain their water supply from lake deposits can have high concentrations of boron, arsenic, fluoride, nitrate, and TDS. The TDS content generally increases toward the central portions of those basins where concentrations have accumulated over time. The groundwater quality along these basin margins tends to be of higher quality, but the potential for future groundwater pollution exists in urban and suburban areas where single-family septic systems have been installed, especially in hard rock areas. Groundwater quality in the alpine basins ranges from good to excellent, but there is potential for degradation in areas where single-family septic systems have been installed, and groundwater contamination has been found from septic tank discharges in urban subdivisions near Susanville and Eagle Lake (DWR 2005). Sampling of 169 public supply water wells from 1994 through 2000 in 8 of the region's 26 basins and subbasins indicate that 147 wells, or 87%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 13%, or 22 wells.

SOUTH LAHONTAN HYDROLOGIC SUBREGION

The South Lahontan hydrologic subregion in eastern California, which includes approximately 21% of the state, covers approximately 21.2 million acres (33,100 square miles). This subregion contains both the highest (Mount Whitney) and lowest (Death Valley) surface elevations of the contiguous United States. It is bounded on the west by the crest of the Sierra Nevada, on the north by the watershed divide between Mono Lake and East Walker River drainages, on the east by Nevada, and on the south by the crest of the San Gabriel and San Bernardino mountains and by the divide between watersheds draining south toward the Colorado River and those draining northward. The northern half of the subregion includes Mono Lake, Owens Valley, Panamint Valley, Death Valley, and the Amargosa River Valley. The southern half of the subregion encompasses a large portion of the Mojave Desert and is characterized by numerous small mountain ranges and valleys with playas. The subregion includes all of Inyo County and parts of Mono, San Bernardino, Kern, and Los Angeles Counties.

Although the quantity of surface water is limited in the South Lahontan hydrologic subregion, the quality is very good, being greatly influenced by snowmelt from the eastern Sierra Nevada. However at lower elevations, groundwater and surface water quality can be degraded, both naturally from geothermal activity, and as a result of anthropogenic activities including recreational uses and cattle grazing. Drinking water standards are most often exceeded for TDS, fluoride, and boron content.

Groundwater near the edges of valleys generally contains lower TDS content than water beneath the central part of the valleys or near dry lakes. The EPA lists 13 sites of contamination in the South Lahontan hydrologic region. Of these, three military installations in the Antelope Valley and Mojave River Valley groundwater basins are federal Superfund sites because of volatile organic compounds and other hazardous contaminants. Sampling of 605 public supply water wells from 1994 through 2000 in 19 of the region's 77 basins and subbasins indicate that 506 wells, or 84%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 16%, or 99 wells.

COLORADO RIVER HYDROLOGIC REGION

The southeast portion of California consists of the Colorado River hydrologic region, which contains 12% of the state's land area. The Colorado River forms most of the region's eastern boundary except for a portion of Nevada at the northeast, and extends south to the Mexican border. The region includes all of Imperial County, approximately the eastern one-fourth of San Diego County, the eastern two-thirds of Riverside County, and the southeastern one-third of San Bernardino County. It includes a large portion of the Mojave Desert and has variable arid desert terrain that includes many bowl-shaped valleys, broad alluvial fans, sandy washes, and hills and mountains.

Water quality issues of concern in this region include increasing levels of salinity, nitrates, and other contaminants in groundwater associated with animal feeding, dairy operations, other agricultural areas, and septic tank systems, especially in the Desert Hot Springs and Cathedral City Cove areas. In the Coachella Valley, high levels of nitrates restrict the use of several domestic water supply wells.

Other water quality issues include groundwater high in TDS content and high fluoride concentrations in many basins, and sulfate content that occasionally exceeds drinking water standards. Two of the primary water quality concerns in the Colorado River hydrologic region are groundwater overdraft in the Coachella Valley and leaking underground storage tanks. Sampling of 314 public supply water wells from 1994 through 2000 in 23 of the Colorado River hydrologic region's 64 basins and subbasins indicate that 270 wells, or 86%, met the state primary MCLs for drinking water standards. Constituents that exceed one or more MCL were found in 14%, or 44 wells. Two Discharge Prohibition Areas have been established in the Colorado River Region—Cathedral City and Mission Creek or Desert Hot Springs Aquifers.

DISINFECTION SYSTEMS

Various methods are available for removing contaminants from effluent. The text below details the effectiveness and practicality of each method.

CHLORINATION

There are few field studies of tablet chlorinators, but those that exist for post-sand-filter applications show fecal coliform reductions of 2 to 3 logs/100 milliliters (ml). Results from one study showing the performance of a tablet chlorinator, evaluated at a flow rate of 1 gal/min, is shown on Table F-2. Total and free chlorine were measured following a 10 minutes of contact time. Approximately 90% of the sampling events resulted in no coliphage or coliform organisms detected in the effluent. In the three separate events where an organism was detected in the effluent, the corresponding free chlorine concentration was less than 1 mg/l (UCD 2006). Another field study of tablet chlorinators following biological treatment units showed exceedances of the standard of 200 fecal coliforms/100 ml 93% of the time, with no chlorine residual present in 68% of the samples. Total suspended solids (TSS) accumulation in the chlorinator, tablet caking, failure of the tablet to drop into the sleeve, and failure to maintain the tablet supply were cited as reasons for these poor results (EPA 2002). Chlorination units must ensure that sufficient chlorine release occurs (depending on pretreatment) from the tablet chlorinator. These units have a history of erratic dosage, so frequent attention is required. Performance is dependent on pretreatment, which the designer must consider. At the point of chlorine addition, mixing is highly desirable and a contact chamber is necessary to ensure maximum disinfection.

Table F-2 Performance of Tablet Chlorination Unit				
Parameter	Unit	Parameter	Performance Value for Indicated Free Chlorine Concentration Range, mf/L ^{1, 2}	
			0 to 1	>1
MS2 coliphage	PFU/ml	Maximum	154,333	0
		Mean	96,541	0
		Log reduction ^{3, 4}	0.8	>5.4
Total coliform	CFU/100 ml	Maximum	21,700	0
		Mean	12,400	0
		Log reduction ^{3, 4}	1.4	>5.6
Fecal coliform	CFU/100 ml	Maximum	1,670	0
		Mean	853	0
		Log reduction ^{3, 4}	2.1	>5.2
Notes: CFU = Colony Forming Units; ml = milliliters; PFU = Plaque Forming Units. ¹ All values reported after 10 minutes of contact time ² Events with free chlorine concentration less than 1 milligrams per liter (mg/l) are estimated to have occurred 10% of the time during the experiment. Organisms were only detected in the effluent when the free chlorine was less than 1 mg/l. ³ Log reduction = -log (effluent concentration/influent concentration) ⁴ Reported as mean log reduction. Source: UCD 2006.				

ULTRAVIOLET LIGHT

Ultraviolet (UV) light is an effective germicide in the wavelength range of 250–270 nanometers. The effectiveness of UV disinfection depends on the ability of the UV light to reach the target wastewater constituents for an amount of time necessary to have the desired effect. Therefore, factors affecting this ability, including the presence of excessive particulate matter, turbidity, dissolved compounds that adsorb UV, short circuiting of flow through the reactor, and accumulation of substances on the lamp housing, can all reduce the effectiveness of UV systems (UCD 2006).

Performance results from one of the UV units evaluated in a study (UCD 2006) are shown in Table F-3. Under optimum conditions, the unit was able to reduce MS2 coliphage and coliform bacteria concentration by 5 log (i.e., 99.999 %). However, the manufacturer's recommended inspection interval is every 6 months, and maintenance may be required more frequently depending on the influent water quality and the level of disinfection desired. The best performance occurred with effluent with TSS concentrations less than 5 mg/l and TSS less than 3 nephelometric turbidity units.

Table F-3 Summary of Performance Characteristics of UV Disinfection System					
Parameter	Unit	Parameter	Performance Value during given Time Period		
			12/15/04–2/3/05 ¹	2/26/05–3/11/05 ²	3/22/05–8/19/05 ³
MS2 coliphage	PFU/ml	Maximum	150	7,400	264
		Mean	58	4,900	21
		Log reduction ^{4, 5}	3.6	1.5	>5.0
Total coliform	CFU/100 ml	Maximum	117	13,133	240
		Mean	48	7,522	24
		Log reduction ^{4, 5}	4.0	2.7	>4.8
Fecal coliform	CFU/100 ml	Maximum	17	1,200	13
		Mean	9	757	1
		Log reduction ^{4, 5}	4.3	3.1	>4.4
Notes: CFU = Colony Forming Units; ml = milliliters; PFU = Plaque Forming Units. ¹ Loading was discontinued on February 3, 2005, and resumed on February 26, 2005; lamp remained on during the entire period of no flow. ² Severe fouling occurred during the 23 d without flow, lamp maintenance occurred on March 11, 2005. ³ Lamp maintenance occurred on 6/6/05 ⁴ Log reduction = -log(effluent concentration / influent concentration) ⁵ Report as mean log reduction Source: UCD 2006					

OZONATION

The use of ozone, a strong oxidant gas, is well established for the disinfection of wastewater in both Europe and in the United States. Ozonation systems are relatively expensive because of the gas transfer facilities needed for transferring adequate concentrations of ozone into water for disinfection, because ozone output is sensitive to the presence of moisture in air and oxygen content in feed gas, and because ozone transfer to water is dependent on temperature, pH, pressure, and design of gas transfer facilities. These factors mean that effective ozonation systems cannot be readily implemented at a low cost at this time (UCD 2006).

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